

The circumstellar environment of pre-SN Ia systems

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Abstract

Here we explore the possible preexisting circumstellar debris of supernova type Ia systems. Classical, symbiotic and recurrent novae all accrete onto roughly solar mass white dwarfs from main sequence or Mira type companions and result in thermonuclear runaways and expulsion of the accreted material at high velocity. The expelled material forms a fast moving shell that eventually slows to planetary nebula expansion velocities within several hundred years. All such systems are recurrent and thousands of shells (each of about $10^{-4}M_{\odot}$) snow plough into the environment. As these systems involve common envelope binaries the material is distributed in a non-spherical shell. These systems could be progenitors of some SN Ia and thus explode into environments with large amounts of accumulated gas and dust distributed in thin non-spherical shells. Such shells should be observable around 100 years after a SN Ia event in a radio flash as the SN Ia debris meets that of the ejected material of the systems previous incarnation.

1 Introduction

Classical novae are exciting objects that are well observed during outburst, but suffer from lack of attention during their quiescence. All classical novae are believed to reoccur, however only those that are seen to are called recurrent novae and do so on human timescales. The more frequent a nova's recurrence the closer it gets to the Chandrasekhar limit. To gain a fuller understanding of the character of evolving nova shells, a campaign to study their morphology, structure and ionization was undertaken. As there are few (~40) known nova shells, a search through IR archives with optical follow-up, has led to the discovery of additional shells. In order to decipher the spatial and velocity constraints of these objects, long-slit high-resolution spectroscopy paired with imaging allows for the construction of three-dimensional morpho-kinematic models.

The time evolution of the ionization structure of novae can also be followed using multi-epoch archival low and medium resolution spectra, which can be simulated using CLOUDY [2] and PYCLOUDY

[3]. The result is a spatial map of specified emission lines and thus modelling the nova shell while quiescent allowing for a greater understanding of nova evolution and giving insight towards the environment as output Nova systems live at the cross-roads of evolution regarding some of the most intensely studied stellar phenomena in astronomy. Classical, symbiotic and recurrent novae occur within cataclysmic variable systems containing a white dwarf and a companion. Symbiotic novae occur within wide binary systems with a Mira and WD, simultaneously pre-PN and post-PN. Classical novae are thermonuclear runaway events within tight binaries on the surface of a WD with a MS star companion from which it accretes again pre-PN and post-PN. Symbiotic, classical, recurrent novae and PNe all share morphological characteristics and are possible SN Ia progenitor systems.

2 Observations

Considering the detectability of the nova shell and planetary nebula surrounding the GK Per system it was decided to search through the WISE archive [4] for hints of IR nebulosity surrounding systems known to harbour classical novae. To follow was an investigation to see if this method would show any results by narrow-band ($H\alpha$ + $[N\ II]$ and $[O\ III]$) optical observations with the Aristarchos 2.3m telescope of previously undiscovered shells in the optical regime. Also, some brighter previously known nova shells and other surrounding material were imaged with the discovery of previously unobserved features in certain systems such as ballistic knots, an ancient PN masquerading as an apparent jet [5] and other nebulosity.

To gain velocity information on the aforementioned imaged features, long-slit echelle spectroscopy were obtained with the Manchester Echelle Spectrometer on the 2.12m telescope located at the San Pedro Martir observatory. To date we have concentrated on nova shells that are > 100 years old, with additional observations of younger nova shells due to take place in August 2016.

3 Modelling

The narrow band $H\alpha$ + $[N\ II]$ Aristarchos imaging coupled with the MES spectroscopy can then be interpreted with the 3D morpho-kinematic code SHAPE [1]. By building 3D spatial structures with velocity, temperature, density plus other modifiers a comprehensive model of a nova shell can be made, with position-velocity arrays or other moment maps as outputs.

From low and medium resolution spectra photoionisation models can be built in either CLOUDY or PYCLOUDY. Through combination of 3D SHAPE models and 1D photoionization models we extract pseudo 3D emission models, see Fig. 1.

4 Conclusions: Recurrent novae growing towards M_{Ch}

For the pre-SN Ia systems described here it is possible for their ejected and swept-up matter to accumulate more than $1 M_{\odot}$ being swept up to a distance of roughly 1 pc. However, before undergoing its SN Ia event the system is expected to undergo nova explosions every ~ 2 months such

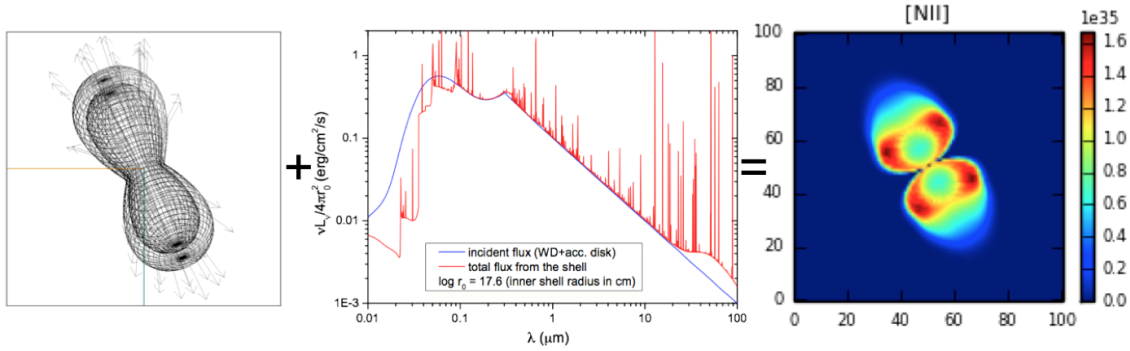


Figure 1: From left to right: a SHAPE model of a bipolar nebula with velocity field lines included, predicted CLOUDY nova shell spectrum, last two panels are PYCLOUDY output showing the expected emission from [N II] 6583 Å.

that the SN Ia ejecta should encounter the most recent nova ejecta around day 6 after ejection, although given the density and energy regimes the SN event would completely dominate the single shell interactions. It is only the accumulated ‘swept-up’ shells that would be detectable with current technology. Since the ejected shells of novae are, in general, non-spherical, and more often than not fragmented into discrete clumps, the material into which the SN Ia is expanding is not uniformly distributed. Estimates for when one of these systems may undergo its SN Ia event can be calculated from equations in [6].

SN Ia occur in complex environments where previous stages of evolution, such as the planetary nebula and cataclysmic variable stages lead to knots, bipolarity, equatorial and polar over-densities surrounding the objects. Through the collective ejection episodes and swept up ISM several solar masses of debris is expected to accumulate in axisymmetric distributions around the SN Ia progenitor systems. This could introduce variations between type Ia SN systems dependent on the line-of-sight towards the object, or even produce the ‘ears’ seen in SN Ia remnants. These features can however be modelled in detail during the progenitor stages of evolution.

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